Meadow fescue and its *Epichloë* endophytes in New Zealand

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Abstract

In New Zealand, meadow fescue (*Festuca pratensis*) was introduced from Europe, along with many other grasses, as Europeans settled in the 1800s. By the 1950s it had fallen completely out of favour and ceased to be used due to its poor agronomic performance. The discovery of an ecotype in Northland in the 1990s, with *Epichloë uncinata* endophyte, stimulated research on this grass and the effect of its endophyte on insect pests. In environments with little insect pressure, trials with meadow fescue generally exhibit pasture yields lower than perennial ryegrass (*Lolium perenne*) and tall fescue (*Festuca arundinacea*). However, in environments with high insect pressure endophyte free meadow fescue can fail in the first year particularly if conditions are dry, while endophyte-infected meadow fescue exhibits strong tolerance to grass grub (*Costelytra zealandica*), black beetle (*Heteronychus arator*) and other insect pests. In these conditions it can perform better than both perennial ryegrass with AR37 endophyte and tall fescue with AR584 endophyte.

Today the use of mixtures of meadow fescue and meadow fescue type Festulolium, with their *E. uncinata* endophyte, has found a niche commercial role on farms in New Zealand due to the protection it provides pastures from a number of insect pests. In addition, mixing meadow fescue with tall fescue has been found to improve palatability over tall fescue alone, with animals leaving lower residuals after grazing, leading to improved quality at subsequent grazings. This provides a solution to the challenge of managing tall fescue on its own. This paper reviews the knowledge about this grass/endophyte combination.

Keywords: *Epichloë uncinata*, *Festuca pratensis*, insect pests, lolines

Introduction

Meadow fescue (*Festuca pratensis* Huds.) is a diploid perennial grass of European origin. It is valued as a pasture grass for its adaptation to cold, northern European temperate regions where winterhardiness is required. It is tolerant to wet soils and known for its perenniality, palatability and poor drought tolerance (Whyte et al. 1959). It has also been shown to lack tolerance to frequent defoliation at low residual sward heights (Casler 2025).

Early European settlers introduced meadow fescue to New Zealand, along with many of the grasses originating from the broader European region. By the 1890s it was eventually valued enough for small scale local seed production in New Zealand (Anon. 1893). It continued to be recommended in some pasture seed mixtures, along with other European grasses, until at least the 1920s (Levy 1923). Its tolerance of waterlogging and swamp-like conditions was valued, and in the early 1900s seed was regularly imported for this use on Northland swamp soils (Lionel Corkill pers. comm.). Volumes were never large and over the years from 1936 to 1944 New Zealand imported on average 13 tonne per year, largely from Denmark, Canada and Germany (Anon. 1947). By the 1950s, meadow fescue was no longer imported or grown for seed commercially in New Zealand (Arnold 1953; Whyte et al. 1959). Subsequent agronomic testing in the 1970s in Canterbury of S53 and S215, two cultivars bred in the UK, showed it to have low yields and to be highly susceptible to Argentine stem weevil (*Listronotus bonariensis*) (Watkin 1974).

In the 1990s, meadow fescue plants were identified growing on a Northland dairy farm in the Kaitaia district and providing valuable summer and autumn feed. This population was found to be highly infected with *Epichloë uncinata* endophyte, a result most probably

ISSN 2463-2872 (Print) ISSN 2463-2880 (Online) https://doi.org/10.33584/rps.18.2025.3767

due to endophyte in the original seed source and selective pressure by insect pests removing endophyte-free plants. This population was found to have superior performance to four overseas meadow fescue cultivars lacking endophyte which failed to persist (Cooper 1996). The endophyte *E. uncinata* produces high levels of loline alkaloids which are now well known for providing resistance to many insect pests (Schardl et al. 2007; Bryant et al. 2010; Caradus & Johnson 2020). When evaluated in Canterbury, experiments comparing endophyte-infected and endophyte-free pastures of this Northland population showed a 42% advantage for the endophyte infected pasture in herbage production by late autumn of year 2 over the endophyte free population. This pasture also had significantly fewer root feeding grass grub (*Costelytra zealandica*) and less weeds (Fletcher et al. 2000; Popay et al. 2003). This was not the first report of meadow fescue infected with *Epichloë* in New Zealand, with Neill (1941) observing *Epichloë* in meadow fescues from five locations and four lines of New Zealand seed. However, the implications of endophyte presence were not understood at that stage.
It is highly likely that the unusual occurrence of meadow fescue in the subtropical environment of Northland, which is in contrast to the cold temperate environments in Europe that it is adapted to, is due to the insect pest tolerance provided by its *Epichloë* endophyte.

The grass, meadow fescue

Festuca pratensis is a diploid with 14 chromosomes. It has undergone various taxonomic treatments, having also been classified as *Schedonorus pratensis* (Huds.) P. Beauv. (Soreng et al. 2001) and *Lolium pratense* (Huds.) Darbysh. (Darbyshire 1993), but here it will be referred to by the older *Festuca pratensis* name.
F. pratensis is related to many polyploids, having contributed a genome to the following (Hand et al. 2010):

- Allotetraploid *F. pratensis* subsp. *apennina* (De Not.) Hegi
- Allohexaploid *F. arundinacea* Schreb. (Continental, Mediterranean and rhizomatous morphotypes)
- Allohexaploid *F. gigantea* (L.) Vill.

As occurs with many European cross-pollinated grasses, a large proportion (65-70%) of the genetic variation within meadow fescue is found within populations and only a small proportion between populations (Kölliker et al. 1999; Fjellheim et al. 2009). Typically, northern European organisms exhibit differences in DNA sequences based on the different glacial refugia they survived in during the last glaciation. These refugia have been identified as occurring in the Iberian Peninsula, Italy, the Balkans and the Caucasus region. The recolonisation of northern Europe by many organisms after the glaciation has commonly been shown to be dominated by one of the refugia populations (Schmitt 2007). In meadow fescue, Fjellheim et al. (2006) showed that Western Europe was colonised from the Iberian glacial refugia. A second molecular group extends from the Balkans across Eastern Europe suggesting a colonisation from the Balkans. A third molecular group occurs in a restricted distribution in the Caucasus, which appears not to have expanded its range since the glaciation. There was only one sample from Italy near the French border, and it was in the Eastern European group. Unfortunately, no samples have been analysed from south of the alps in Italy, which could potentially contain survivors from an Italian glacial refugia.

A rhizomatous form of meadow fescue containing endophyte occurs in the grasslands of the Tramelan region of the Jura Mountains of western Switzerland, at 1020 m altitude (Mastrullo 1990; Malinowski 1995). In molecular studies of ecotypes in Switzerland three distinct groups were detected one of which was from this region (Pieter-Schmid et al. 2008).

Vegetatively reproducing triploid hybrids of diploid *F. pratensis* and tetraploid *F. pratensis* subsp. *apennina* are abundant at altitudes between 1100 and 1900 m above sea level in the Swiss Alps (Kopecký et al. 2018). Seedling establishment of meadow fescue is slower than perennial ryegrass and is more like tall fescue. For example, in an unpublished trial sown at Kirwee, Canterbury on 22 February 2019, Legion AR37 perennial ryegrass yielded 2520 kg/ha DM at the first cut on 31 July, significantly more than Hummer AR584 tall fescue at 720 kg/ha DM and Oakdon AR1017 meadow fescue at 350 kg/ha DM.

Commercial seed production of meadow fescue is likely to be over 6000 tonnes internationally. In 2015 the production in the EU was over 5300 tonnes from 9247 ha (Wong 2018) and although recent seed production data is not available, in 2007 the areas produced in the EU, Canada and Norway were 12,343 ha, 1163 ha and 643 ha respectively (Bondesen 2007). In comparison, the production in New Zealand in 2025 was less than 50 tonnes.

Festulolium

The term Festulolium refers to any cross or backcross between *Festuca* and *Lolium* species. Festuloliums with *F. pratensis* as one parent commonly include crosses with *L. multiflorum* or *L. perenne.* The cross with *L. multiflorum* is usually assigned the taxonomical name ×*Festulolium braunii* K. Richter, while that with *L. perenne* is assigned ×*Festulolium loliaceum* Huds.

(Kopecký & Kosmala 2021). These crosses may be made at the diploid or tetraploid level, but most resulting cultivars are tetraploid. By backcrossing, it is possible to introgress traits from one species to the other, and a number of diploid cultivars have been made using this method (Zwierzykowski & Kopecký 2021). Often the proportion of the introgressed species is very small and they function very similarly to the dominant parent, but as they still have some detectable traces of DNA from the other species, they may still be termed Festulolium. The proportion of *Festuca* and *Lolium* DNA in tetraploid hybrids is not stable, and over eight or more generations the hybrid will lose portions of *Festuca* chromosomes and become predominantly *Lolium* chromosomes (Majka et al. 2021).

Cultivars

The meadow fescue cultivar Oakdon was bred in New Zealand by Grasslands Innovation Ltd from Swiss germplasm, after undertaking nine cycles of selection for disease resistance, productivity, winter growth, seed yield, seedling vigour, and content of a single strain of its natural *E. uncinata* endophyte AR1017. It was commercially released in 2021.The Festulolium cultivar Barrier was developed in New Zealand by Cropmark Seeds, commercially released in a mixture in 2014 and sold with the *E. uncinata* endophyte U2. This Festulolium has a predominance of meadow fescue with a very small proportion of *Lolium*.

There have been numerous meadow fescue cultivars developed in Europe and some in Japan and USA. In Europe, several tetraploid cultivars of meadow fescue have been developed. These cultivars usually have larger plant organs, such as seeds, leaves and tillers, but also fewer tillers, reduced seedheads, and head 2-4 days later than equivalent diploid cultivars. This is typical of many grasses when the chromosome number is doubled, a phenomenon known as the gigas effect (Easton 1977). Meadow fescue cultivars are prone to seed shattering during seed production and selection against this trait has been the subject of much breeding, but to date has not been successful (Simon 1993; Wójtowicz & Zieliński 2021; Kavka et al. 2024).

Endophyte

Meadow fescue can be infected with the asexual endophyte *E. uncinata* (formerly *Neotyphodium uncinatum* (Leuchtmann et al. 2014)), a hybrid of *E. bromicola* and *E. typhina* (Craven et al. 2001). In addition, a single occurrence has been reported of a second endophyte *E. siegelii,* a hybrid of *E. amarillans* and *E. elymi* (Craven et al. 2001).

In Europe, endophyte infection is common in many ecotypes, and many cultivars can contain endophyte, although levels of infection vary depending upon breeding and seed maintenance procedures (Koh et al. 2006; Puentes et al. 2007; Saari et al. 2009; Bylin et al. 2014; Kauppinen et al. 2016; Pfannmöller et al. 1997; Cagnano et al. 2019; Vikuk et al. 2019). Using SSR markers Barker et al. (2015a) identified four *E. uncinata* groups: one each from Norway and Bulgaria, and two from Germany.

Impacts on plant growth

The presence of endophyte can have a significant effect on plant growth responses, and physiology as well as influencing other organisms that are seeking to consume the host plant. In studies comparing endophyte infected and endophyte free plants, endophytic plants have been shown to have significantly more tillers (8%), although this does not necessarily result in extra plant biomass (Bylin et al. 2014). However, endophyte infection has been reported to promote both shoot and root growth, tiller number, stomatal resistance and reduced leaf xylem potential (Malinowski 1995) and significantly increased plant height, number of flowerheads and chlorophyl content (SPAD value) (Mathew et al. 2023).

Endophyte infected plants also resulted in significantly higher auxin concentrations (indole acetic acid and phenyl acetic acid) and reduced levels of the phytohormone salicylic and influenced the fungal community in leaves, but not the bacterial community (Mathew et al. 2023). Plausible salt tolerance has also been considered to result from endophyte infection reducing Na+ and Cl– concentrations in meadow fescue roots but increasing K+ concentrations in the shoots (Sabzalian & Mirlohi 2010). Studies by Casler & Waldron (2023) on drought survival found no consistent impact due to endophyte. Casler (2025) found that meadow fescue persistence under frequent defoliation to low residual sward heights could be improved by endophyte presence as well as through genetic selection.

Lolines

In meadow fescue both *E. uncinata* and *E. siegelii* produce high concentrations of loline alkaloids, usually more N-formylloline than N-acetylloline and N-acetylnorloline and they are not known to produce any toxic ergopeptides (ergovaline) or indole-diterpenes (lolitrem B) (Patchett et al. 2011b; Bylin et al. 2014; Cagnano et al. 2019; Vikuk et al. 2019). Loline alkaloid levels can reach 0.65% dry matter (DM) (6500 ppm) in reproductive tillers, 0.3% DM (2500 ppm) in leaf and 0.2% DM (2000 ppm) in roots (Patchett et al. 2011b; Realini et al. 2024). In seed, lolines can be up

to 1.9% DM (19500 ppm) in meadow fescue and even higher at 3% DM in a meadow fescue type Festulolium (Popay & Tapper 2007; Barker et al. 2015a). During germination approximately 20% of total lolines are lost by leaching during seed imbibition (Justus et al 1997). Levels in foliage and roots increase with increased soil phosphate (Hewitt et al. 2024) and can vary with season (Fletcher et al. 2000; Patchett et al. 2011b). Lolines are water soluble and translocate to the roots but levels in the roots are consistently lower than those found in the foliage (Hewitt et al. 2024). Lolines appear highly responsive to many factors including clipping or grazing, with grazing also increasing the translocation rate to roots (Decunta et al. 2025).

Lolines and insect pests

The loline alkaloids are well known for providing resistance to many insect pests (Table 1). Studies by Patchett et al. (2011a) showed that grass grub either lost weight or gained less weight when feeding on roots of meadow fescue with >450 ppm lolines than when feeding on endophyte free meadow fescue. Popay et al. (2020) showed that drought increased loline levels and grass grub root feeding was reduced compared to well-watered plants. However, even at lower levels of lolines, grass grub survival rate is significantly lower than when fed on plants that did not contain a loline-producing endophyte strain (Hewitt et al. 2024).

In perennial ryegrass with wild type endophyte the alkaloid peramine is produced which controls Argentine stem weevil adult feeding and oviposition. Neither *E. siegelii* nor *E. uncinata* produce peramine due to mutations in the peramine gene (Berry et al. 2015). Despite this lack of peramine, meadow fescue endophyte infection has been found to reduce oviposition of Argentine stem weevil, but it had no impact on adult Argentine stem weevil feeding scores (Jensen et al. 2009). This valuable insect tolerance feature is unique among grasses and enables the species to be used in subtropical climates in the north of New Zealand where extreme pest pressure exists.

Lolines and livestock

Lolines are not known to cause any animal health and welfare issues when consumed by grazing ruminants (Daccord et al. 1995; Fletcher et al. 2000; Schardl et al. 2007; Gootneratne et al. 2012). In an *in-vitro* study, lolines showed little evidence of an antimicrobial effect on rumen microbes with only a slight alteration to the rumen-fermentation pattern (Froehlich et al. 2019). Only 4% of the lolines ingested by sheep were detected in dung (Gootneratne et al. 2012). Dosing sheep orally with lolines has also failed to show any effect on gastrointestinal nematodes (Froehlich et al. 2022).

Meadow fescue endophyte strains

A number of meadow fescue endophytes have been registered for Plant Variety Rights (PVR) in New Zealand, although it appears that only U2 and AR1017 (trademarked under the name MaxR®) have been effectively used commercially (Table 2).

Interspecies transfer of endophyte

To improve the pest protection profile of ryegrass without compromising livestock health and performance, attempts have been made to transfer high loline producing endophytes from tall fescue and meadow fescue, to enable loline expression in perennial ryegrass and Italian ryegrass (*L. multiflorum*) (Matsukura et al. 2012; Johnson et al. 2019). While this interspecies transfer of *Epichloë* has been achievable through inoculation and backcrossing, commercial application has been seriously hindered by sub-optimal loline expression, difficulties in transmission to seed and poor longevity in storage, highlighting the strong host specificity of *Epichloë* endophytes (Johnson *et al.* 2019; Caradus & Johnson 2020). It is possible that gene editing or genetic modification may be required to improve these traits, although the genetic basis of these is not currently understood.

Agricultural use

The use of meadow fescue and meadow fescue types of Festulolium, with their *E. uncinata* endophyte, have found a small but effective commercial niche on farms in New Zealand due to the endophyte's effects on a wide range of insect pests, in particular the unique resistance to the root-feeding larval pests of grass grub and black beetle. As well as insect protection, *E. uncinata* endophyte infection may increase the drought tolerance and so the competitive ability of meadow fescue in the field (Malinowski et al. 1997a; Malinowski et al. 1997b). The use of meadow fescue in mixtures is possible as Cooper (1996) reported the benefits of the ecotype of meadow fescue in Northland when combined with a multi-species pasture on-farm.

Agronomic performance

In trials under moist New Zealand conditions, meadow fescue yield is usually less than that for perennial ryegrass and tall fescue, but endophyte infected plants show better persistence than plants lacking endophyte (Cooper 1996; Fletcher et al. 2000; Hume et al. 2009). However, the magnitude of the differing agronomic performance varies with latitude with the largest differences occurring in winter. Winter performance

Table 1 Insect resistance provided by *Epichloë uncinata* endophyte in meadow fescue and/or meadow fescue-type Festulolium.

Organism	Impact	Alkaloid	Reference
Heteronychus arator - black beetle	Deterrent, antifeeding effect on larvae and adult stages	Lolines	Bryant et al. 2010 Ball et al. 1994 Barker et al. 2015a
Lepidogryllus spp. - mottled field cricket	Deterrent	Lolines	Barker et al. 2015b
Teleogryllus commodus - black field cricket	Deterrent	Lolines	Barker et al. 2015b
Trigonotylus caelestialium - rice leaf bug	Resistance	Lolines	Shiba & Sugawara 2009
Wiseana cervinata - porina	Reduce feeding and weight gain	Lolines	Popay and Lane 2000
Adoryphorus coulonii - red-headed cockchafer	Reduced (10–20%) root consumption at >1000 μg/g DM lolines	Lolines	Bryant et al. 2010
Aploneura lentisci - root aphid	Reduced root aphid numbers per plant	Possibly lolines	Schmidt 1993 Schmidt & Guy 1997
Costelytra zealandica or *C. giveni* - grass grub	Reduced root feeding and larval weight gain; a deterrent effect	Lolines and increased levels due to grass grub attack	Patchett et al. 2008a Patchett et al. 2011c Popay & Latch 1993 Popay & Ball 1998 Fletcher et al. 2000 Popay & Lane 2000 Popay et al. 2003 Popay & Tapper 2007 Popay et al. 2020 Popay et al. 1993 Popay et al. 2003 Bryant et al. 2010
Listronotis bonariensis - Argentine stem weevil	Feeding deterrent and death of larvae	Loline level >400 μg/g DM; NANL possibly more potent than NFL at moderate concentrations	Popay & Latch 1993 Patchett et al. 2008b Jensen et al. 2009 Popay et al. 2009
Schizaphis graminum - aphid	Toxic causing reduced numbers	Lolines	Riedell et al. 1991 Wilkinson et al. 2000
Balanococcus poae - pasture mealybug	Strong provisional rating for control	Probably lolines	Industry ETC tables as published in Caradus et al. 2021

Table 2 Endophytes granted Plant Variety Rights in New Zealand.

Endophyte strain	Year PVR granted	Owner	*Epichloë* species	Sold in commercial cultivar
U2	2008	Cropmark	*E. uncinata*	'Barrier' Festulolium (meadow fescue type)
UNC1	2008	Cropmark	*E. uncinata*	
Happe	2010	DLF	*E. siegelii*	Was sold in perennial ryegrass only in limited quantities
U12	2014	Cropmark	*E. uncinata*	
AR1006	2015	Grasslanz	*E. uncinata*	
U13	2016	Cropmark	*E. uncinata*	
AR1017	2016	Grasslanz	*E. uncinata*	'Oakdon' MaxR® meadow fescue

Table 3 Relative mean seasonal and annual yields of meadow fescue, ryegrass and cocksfoot (*Dactylis glomerata*), compared to the mean trial yield, and ground cover scores, in a 3-year cutting trial, sown in autumn 2015 near Whangārei, Northland.

Species	Cultivar & endophyte strain	Winter	Spring	Summer	Autumn	Year	Cover score*
Perennial ryegrass	One50 AR37*** (yield kg DM/ha)	100 ab** (3003)	100 b (7120)	100 b (2723)	100 bd (3371)	100 c (16240)	8.3 a
Perennial ryegrass	Nui, No endophyte	100 ab	94 b	70 c	90 d	90 d	3.5 c
Meadow fescue	Oakdon AR1017	80 c	101 b	153 b	103 bc	106 b	9.0 a
Cocksfoot	Savvy	97 ab	106 a	197 a	139 a	127 a	8.8 a

* 9 = 90% or greater sown grass cover (i.e. no gaps in drill rows), 1 = 10% or less sown grass presence (i.e. few plants in drill rows) 3 years after sowing

** Letters signify significance within a column using Duncans test (P<0.05).

*** AR37 *Epichloë* species LpTG-3

Table 4 Relative mean seasonal and annual yields of Hummer tall fescue and Oakdon meadow fescue, compared to Quantica tall fescue, in a 3-year irrigated cutting trial, sown in autumn 2016 at Kimihia Research Centre, Canterbury.

Species	Cultivar & endophyte strain	Autumn	Winter	Spring	Summer	Annual total
Tall fescue	Quantica AR584** (yield kg DM/ha)	100 a* (3830)	100 a (2750)	100 a (6420)	100 a (3870)	100 a (16870)
Tall fescue	Hummer AR584	94 a	82 b	104 a	96 a	96 a
Meadow fescue	Oakdon AR1017	62 b	30 c	90 a	80 b	71 b

* Letters signify significance within a column using Duncans test (P<0.05).

** AR584 trademarked as MaxP® *Epichloë coenophiala*

Table 5 Relative mean seasonal and annual yields of perennial ryegrass and meadow fescue cultivars, compared to Samson perennial ryegrass, in a 2-year irrigated cutting trial, sown in autumn 2016 at Kimihia Research Centre, Canterbury.

Species	Cultivar & endophyte strain	Autumn	Winter	Spring	Summer	Annual total
Perennial ryegrass	Samson AR37 (yield kg DM/ha)	100 a* (1680)	100 a (1540)	100 a (6930)	100 a (1760)	100 a (11910)
Perennial ryegrass	Platform AR37	92 a	87 b	99 a	80 b	94 a
Meadow fescue	J201 AR1006**	41 c	11 d	88 b	79 b	70 b
Meadow fescue	Oakdon AR1017	74 b	39 c	69 b	57 c	64 b

* Letters signify significance within a column using Duncans test (P<0.05).

** Line J201 AR1006 is derived from the Northland ecotype collected by Cooper (1996).

of meadow fescue is considerably lower than ryegrass and tall fescue in cooler southern temperate environments such as Canterbury, but only slightly lower than these species further north, particularly in the subtropical environment of Northland. In a 3-year trial in Northland, during a period of moderately high black beetle pressure, meadow fescue with endophyte performed better than both perennial ryegrass with and without endophyte, while cocksfoot performed best (Table 3). Meadow fescue plots maintained complete ground cover while endophyte free perennial ryegrass had less than 35%.

In contrast to Northland, typical trials in Canterbury, a region where winters are cool and summers are dry, and there is no pest pressure from black beetle, meadow fescue has significantly lower yields than tall fescue with AR584 and perennial ryegrass with AR37 in all seasons except spring (Table 4 and 5). This was particularly prominent in winter, where meadow fescue yielded only 30% of tall fescue (Table 4) and 11 to 39% of perennial ryegrass (Table 5).

Meadow and tall fescue mixtures

The insect tolerance of meadow fescue can provide significant value in pasture mixtures, but there are also other reasons why meadow fescue can provide benefit in pasture mixtures, many of which can be termed ‘ecosystem services’. Despite the lower yields of

Table 6 Palatability (grazing preference score), metabolisable energy, pasture yield pre-grazing and pasture utilisation of mixed pastures of Hummer AR584 tall fescue with Oakdon AR1017 meadow fescue compared to pure tall fescue Hummer AR584 tall fescue under grazing through spring and summer of the year when tall fescue becomes reproductive and stemmy in a trial sown March 2019 at Pencarrow, Waikato. Summer 2021 was very dry.

Measurement	Date	Tall & meadow fescue mixture	Pure tall fescue
Grazing preference score*	26 Sept 2019	6.1 a*	3.4 b
	11 Nov 2019	4.7 a	2.7 b
Metabolisable energy (MJ/kg DM)	30 Sept 2020	11.7**	11.0
	27 Oct 2020	10.6	10.4
	20 Nov 2020	10.0	9.4
Pre-grazing yield (kg DM/ha)***	8 Jan 2021	805 a	975 a
Utilisation %	8 Jan 2021	46	33
Pre-grazing yield (kg DM/ha)	11 Feb 2021	647 a	887 a
Utilisation %	11 Feb 2021	59	32
Pre-grazing yield (kg DM/ha)	15 Mar 2021	755 a	757 a
Utilisation %	15 Mar 2021	91	82
Pre-grazing yield (kg DM/ha)	21 Apr 2021	1045 a	1252 a
Utilisation %	21 Apr 2021	92	92

* 9 = highly preferred 1 = least preferred.
** Replicates bulked for quality analysis, so no statistical analysis was possible.
*** pre-grazing yield is the amount of herbage above 4 cm. Utilisation is the proportion of herbage above 4 cm that was removed by grazing.
Letters signify significance within a column using Duncans test (P<0.05).

Table 7 Relative mean seasonal and annual yields of Oakdon meadow fescue and a mixture of Hummer tall fescue and Oakdon meadow fescue, compared to Hummer tall fescue, in a 3-year cutting trial, sown in spring 2020 in Central Hawke's Bay.

Species	Cultivar & endophyte strain	Winter	Early spring	Late spring	Summer	Autumn	Annual total
Tall fescue	Hummer AR584 (yield kg DM/ha)	100 ab* (880)	100 a (2440)	100 a (3010)	100 abc (5450)	100 a (3070)	100 a (14950)
Meadow fescue	Oakdon AR1017	93 b	82 b	92 a	95 bc	99 a	93 ab
50:50 mixture	Hummer/Oakdon	98 ab	96 a	102 a	102 ab	99 a	100 a

* Letters signify significance within a column using Duncans test (P<0.05).

meadow fescue pastures than that of perennial ryegrass and tall fescue its palatability in spring helps counteract the spring stemminess of tall fescue which reduces its palatability for livestock. Tall fescue has not achieved its full on-farm potential in New Zealand due to the difficulty of controlling reproductive stem growth in spring and summer, and more exacting management requirements overall. It is essential that it is frequently grazed or mown to maintain quality during this period of the year, but this is not always achievable on-farm (Milne et al. 1997). By mixing meadow fescue with tall fescue, each with their respective endophytes, pasture palatability can be increased considerably, grazing residuals reduced resulting in greater pasture utilisation, and quality can be maintained, compared to tall fescue-only pastures (Table 6). To date, trials have been sown at a 50% mixture of the tall fescue and meadow fescue, but more research may be required to optimise this in different regions.

Yields of the tall fescue and meadow fescue mixtures and pure tall fescue are very similar in Central Hawke's Bay (Table 7), but this may depend upon pest pressure and grazing management.

Conclusion

In New Zealand the performance of meadow fescue with endophyte is usually below that of perennial

ryegrass and tall fescue , particularly in winter, but the endophyte is unique in providing excellent resistance to root feeding insects such as grass grub and black beetle. This is achieved through translocation of loline alkaloids to the roots. The level of lolines in the roots are highly responsive to grazing and root damage, and under conditions where root feeding pests, particularly grass grub and black beetle, are severe, meadow fescue with endophyte is often the only grass to survive. Developing endophytes that can produce high levels of lolines in the roots of host grasses while functioning effectively in high-yielding species such as perennial ryegrass and tall fescue has been a long-term research aim for control of grass grub and black beetle. It may be necessary to use gene editing or genetic modification to achieve this.

A meadow fescue with endophyte is now commercially available and can be used as either a stand-alone option or in mixtures with endophytic tall fescue which provides an option to solve the difficulty of controlling seedheads and reduced quality of pure tall fescue pastures in the spring/summer period.

ACKNOWLEDGEMENTS

The authors would like to thank Marie Schwartz, Alexia Becroft, Dylan Moratti, Blake Gunn, Kylie Dobbs and Agricom staff for undertaking the agronomic trials and Ellen Hume, John Caradus, Wayne Nichol and Allister Moorhead for reviewing the manuscript.

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